2919 .
$1.00

a self-guided Auto tour

CRATERS ▲ CONES ▲ COULEES

Inyo National Forest & E.S.I.A.

Watch for the "AUTO INTERPRETIVE TRAIL" signs!!

book written in a foreign language.
ed by the tremendous forces of earth-
the earth. This tour will help you
ıd. You will visit in a few miles and
ıd on earth.

still-bubbling hot springs to lava flows, both
anic processes working over long periods of
such as craters, cones, coulees and more.
hikes and drives, taking you deeper into the
story, will be suggested.

Birdseye view of Mono Craters.

We recommend you follow the tour from south to north to minimize turning across traffic on Hwy. 395. Always drive with care and carry plenty of drinking water.

As you tour and explore the region you will find glassy obsidian, a common volcanic rock used by Native Americans to make many tools. You may see the remains of tool making activity in different locations. Please leave anything you see on the ground for others to enjoy. *REMEMBER: Federal law prohibits artifact collecting.*

LONG VALLEY CALDERA (from Mammoth Ranger Station) As you drive east on Hwy. 203, you will descend into a valley that was the source of such a violent eruption that it would have made Mt. St. Helens look like a small burp. 700,000 yrs. ago this powerful explosion sent hot gases and ash miles into the air: an inch-thick layer of ash was deposited as far away as Nebraska. Geologists believe the eruption partially emptied the underground chamber of its magma (hot, liquid lava), allowing the ground surface above the chamber to collapse. Such a large sunken hole is called a caldera. Long Valley Caldera is a valley 10 miles wide by 18 miles long, extending from Crowley Lake to the Crestview grade and from Mammoth Mtn. to Glass Mtn.(see map).

Geologically speaking, the mountains, domes, and ridges here are very young and still changing. The features of the Long Valley landscape arose or fell after the roof of the caldera collapsed. Watch for rock fields or outcrops, study the ridges on either side of the highway and try to identify volcanic domes. Most features you see, except the Sierra Nevada to the west, are volcanic. As you begin to see the differences in rock color, texture and size you are like a scientist trying to puzzle out the language of volcanoes.

1. HOT CREEK FISH HATCHERY *(South on Hwy. 395, 3 miles, turn east at the airport turn-off, .9 mile, follow signs)*

A chamber of hot, molten magma remains deep beneath the earth's surface. In addition, channels of water circulate among the layers of rock overlaying the magma. Where the water comes in contact with these heated rocks, the water picks up heat in a process called geothermal heating. At the hatchery, springs of this geothermally heated water rise naturally to the surface. Water from four different springs mixes with the cold water of Mammoth Creek to create ponds ranging in temperature from 52-62 degrees F. The ponds provide an ideal environment for incubating trout eggs and raising fish. While each pond is a different temperature from the others, each maintains its temperature year 'round despite changes in the weather and water flow. Hot Creek Hatchery was built in the early 1930's and is operated by the California Department of Fish and Game. It is open to the public daily.

2. HOT CREEK GEOLOGIC SITE *(Continue eastward on dirt road past the hatchery, 2.3 miles)*

Looking into the Hot Creek gorge from the interpretive sign you will see two typical geothermal features: boiling hot springs and fumaroles (steam vents). In addition you may notice a sulfuric odor, and the walls of the gorge are an unusual yellow color.

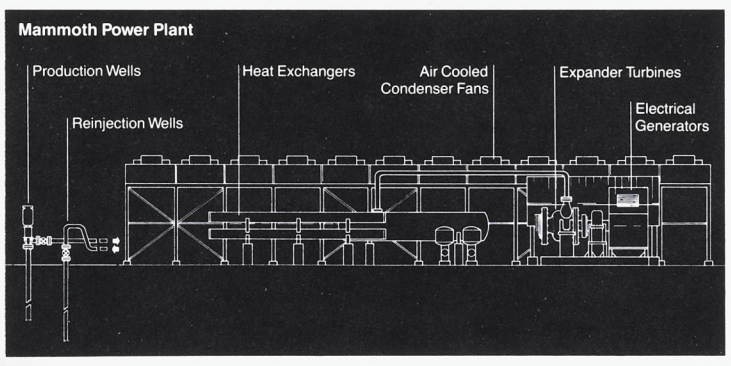
Each of these features is similar to those seen in Yellowstone National Park. Like the features in Yellowstone, these owe their existence to hot magma deep in the earth. The yellow rock has been altered by contact with geothermally heated water. The sulfur smell is associated with the heat of the magma chamber, but the magma is not rich in sulfur. And the boiling hot springs and the steaming fumaroles are obvious indications of subterranean heat. Earthquakes and underground magma activity may change the location or intensity of springs and fumaroles overnight.

Why do the pools appear blue? An optical illusion occurs where light reflects off white calcium carbonate crystals causing you to see blue.

3. CASA DIABLO HOT SPRINGS *(Return north on Hwy. 395 to Hwy. 203. Turn east on Hwy. 203, .3 mile, turn left at end of road for .3 mile.)*

About 600 feet under your feet, the Mammoth-Pacific Geothermal Power Plant wells tap into a reservoir of geothermally heated water. The 340 degree water is pumped to the machinery you see here, passed through heat exchangers and converted to electricity. The plant produces 8,000 kilowatts of electricity, an amount that would meet one-third of Mammoth Lakes' summer demand for power.

The history of volcanic activity in this area indicates future potential. Many areas in the Eastern Sierra are classified as Known Geothermal Resource Areas and are under consideration for development of additional power plants such as this one.



K. Meyer

4. MAMMOTH MOUNTAIN VISTA *(Return to end of Hwy. 203, turn right and park for this stop.)*

You can identify Mammoth Mountain by the ski slopes and lift structures on the horizon. Although well-known as a ski resort, few people realize Mammoth Mountain is a quiescent (dormant) volcano. Over time, 250,000 to 50,000 years ago, Mammoth Mountain erupted and flowed, building on the rim of the Long Valley Caldera.

One way geologists determine the age of rock and the sequence of past events is by identifying the color, texture, weight and chemistry of different layers of rock and sediments. However, rock may be removed by natural forces such as wind and water, and by humans. On Mammoth Mountain, the story is complicated by glaciers, large ice sheets which move rocks and take them out of sequence. Mammoth Mountain's volcanic history is told by its ash layers and lava flows and changed by the action of wind, snow, ice and humans.

5. SMOKEY BEAR FLAT *(Hwy. 395 north 3 miles to large sand flat and Smokey sign.)*

Walk beyond the sagebrush surrounding the turn-out into the flat of gravel-sized rocks. Take a moment to sort a few rocks into piles by color, texture and weight. The lightest color (here) is usually the lightest in weight. This is pumice, a rhyolitic (rye-o-li-tic) rock from an explosive eruption. Pumice is sent flying high into the air by the force of the explosion and may be carried further by the wind. Larger and heavier particles land close to the source of the eruption, while small ash and rock particles travel further. The Smokey Bear Flat pumice probably originated in the Inyo Craters eruption 500-600 years ago. Small plants such as pink and yellow monkeyflower often carpet pumice flats in the spring, but neither trees nor sagebrush will grow in these flats. Why not? Perhaps the pumice lacks essential nutrients. Perhaps there is not enough water or the water is too deep for the plants to reach. Scientists are not sure. What do you think?

Adventurers may wish to visit the Inyo Craters, Earthquake Fault and Devils Postpile from the Scenic Loop Road 2 miles north.

6. LOOKOUT MOUNTAIN *(Hwy. 395 north 2 miles, then 3 miles east on Lookout Mtn. Road, not recommended for buses.)*

A rough road leads to an eagle's view of the Long Valley Caldera and other volcanic features you have seen or will see from the ground. Walk along the top of Lookout Mountain. As you look around, you will see that Lookout Mtn. is one of the many resurgent domes (uplifted after the collapse of the caldera) within the valley you now know as the Long Valley Caldera. Look for Crowley Lake to the south, Mammoth Mountain to the west, Hwy. 395 to the north and Glass Mountain (the long ridge beginning with Bald Mountain Fire Lookout) to the east. These landmarks form the edges of the Long Valley Caldera. By comparison, the caldera left behind from the 1980 Mount St. Helens eruption was about one mile in diameter.

At your feet you will find both pumice and a new rock: obsidian. Although they look very different, these two rocks are the same. Imagine a bottle of soda pop or mineral water. When you look at the sealed bottle you see a liquid of uniform consistency. Now if you shake the bottle and remove the cap, the pressure is released and gas bubbles form which may shoot off in an "explosion". A rhyolitic explosion is a similar process. Pressure on the magma is reduced as the magma rises to the earth's surface. Some of the molten material expands and explodes, forming bubbles (pumice), while some retains its original texture and cools into the glassy fragments (obsidian).

Native Americans quarried obsidian from these resurgent domes and elsewhere. The people worked the glassy stone to make cutting tools such as points, scrapers and knives. Obsidian was a valuable trade item. Anthropologists have found tools from Eastern Sierra quarries throughout North America. Obsidian is still the sharpest cutting material known.

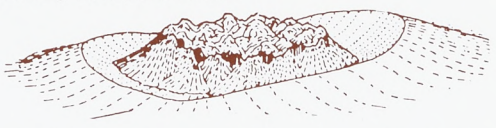
7. OBSIDIAN DOME *(North on Hwy. 395, 5.6 miles, then west on Glass Flow Road 1.4 miles.)*

To understand how obsidian is extruded from the earth, imagine holding a tube of toothpaste upright and slowly squeezing the tube. The thick, viscous material forms a column which will fall quickly for lack of solid support. Now go a step further and imagine that instead of toothpaste, your tube is full of melted glass (like obsidian). When the column of glass comes into contact with air, the outside cools and stops moving. The inside of the column keeps moving because it is still under pressure. What do you think might happen? The outside surface becomes a brittle skin that cracks and falls away. Imagine the obsidian column oozing from the earth, cooling and breaking off.

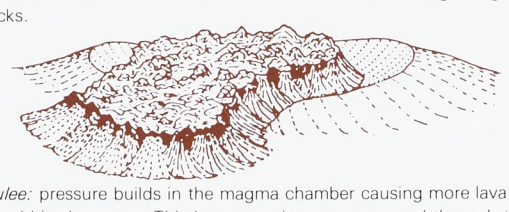
8. DEVILS PUNCHBOWL *(North on Hwy. 395, 3.1 miles, then 1.7 miles east on Pumice Mine Road, follow signs.)*

The Devils Punchbowl is a small crater formed by an explosive, rhyolitic eruption. Do you recognize the gravel-sized pumice thrown out by the violent event? Another term for this type of eruption is phreatic (free-ah'-tic) meaning the magma passed through the underground water table as it rose. The magma came into contact with and heated the water, adding steam to the eruption. Gravel-sized particles fell close to the source of the explosion creating the rim where you stand, while the lighter fragments and ashes were blown further away. The small dome inside the crater built after the phreatic eruption. Return to the highway on the same road.

Explosion Pit: the result of a plinian eruption, a violent explosion of water-laden lava that sends clouds of ash and small rocks miles into the air. The lightest particles of ash are carried away on the wind, while heavier ash and small rocks accumulate as a rim or cone surrounding the explosion crater.



Dome building: viscous, slow-moving lava rises through a fault or vent within the crater. As the lava cools, it breaks into large, angular blocks.



Coulee: pressure builds in the magma chamber causing more lava to rise within the crater. This lava extrusion runs over and through the rim surrounding the original crater and dome, appearing as a short, thick flow of large volcanic blocks.

Hill, Mary. Geology of the Sierra Nevada

9. MONO CRATERS VISTA *(North Hwy. 395, 2.3 miles to West Portal Road, then .7 mile east to large clearing.)*

The eerie landscape before you is the 10-mile long chain of Mono Craters. Here many eruptions created abutting and overlapping domes, flows and craters. The light grey color and the pumice at your feet tell you the Mono Craters, like most of the volcanoes in this area, are rhyolitic. Would you expect to find obsidian in the craters?

The first stage of of a rhyolitic eruption is called either a Plinian (plin'-ee-an) eruption, after Pliny the Elder, who first described it or a phreatic eruption (see Devils Punchbowl). Dome building and coulee flow are the second and third stages typical of rhyolitic eruptions (see illustration). Eruptions in the Mono Craters began at least 40,000 years ago and continued until recently, with the last eruption about 600 years ago.

The Mono Craters are mined for pumice blocks in the only such operation in the United States. These blocks have a variety of industrial uses including restaurant grill cleaners, landscaping and the rock that creates fashionable stone-washed jeans. Watch for pumice products when you shop. Any product marked "US Pumice" comes from the Mono Craters.

10. AEOLIAN BUTTES *(Turn north on one-lane dirt road, .9 mile.)*

The pinkish-colored Aeolian Buttes were deposited by the immense explosion that created the Long Valley Caldera, 700,000 years ago. Fiery clouds of ash spread in all directions from the Long Valley area. The ash compacted and welded into a blanket of relatively soft rock, called Bishop tuff. Later volcanic and glacial activity deposited ash, rock and debris on top of the tuff. Wind and rain eroded the exposed tuff to the forms now visible.

Wander among the rocks looking for crystals, lenses of obsidian (called fiami [fee-ah'-mee]) and signs of wind and water erosion. How does this rock compare to rocks you've seen elsewhere? Can you tell the difference between the soft tuff and harder granite (the rock normally found in the High Sierra)?

M. Ambrose

Mono Craters.

Inyo National Forest & E.S.I.A.

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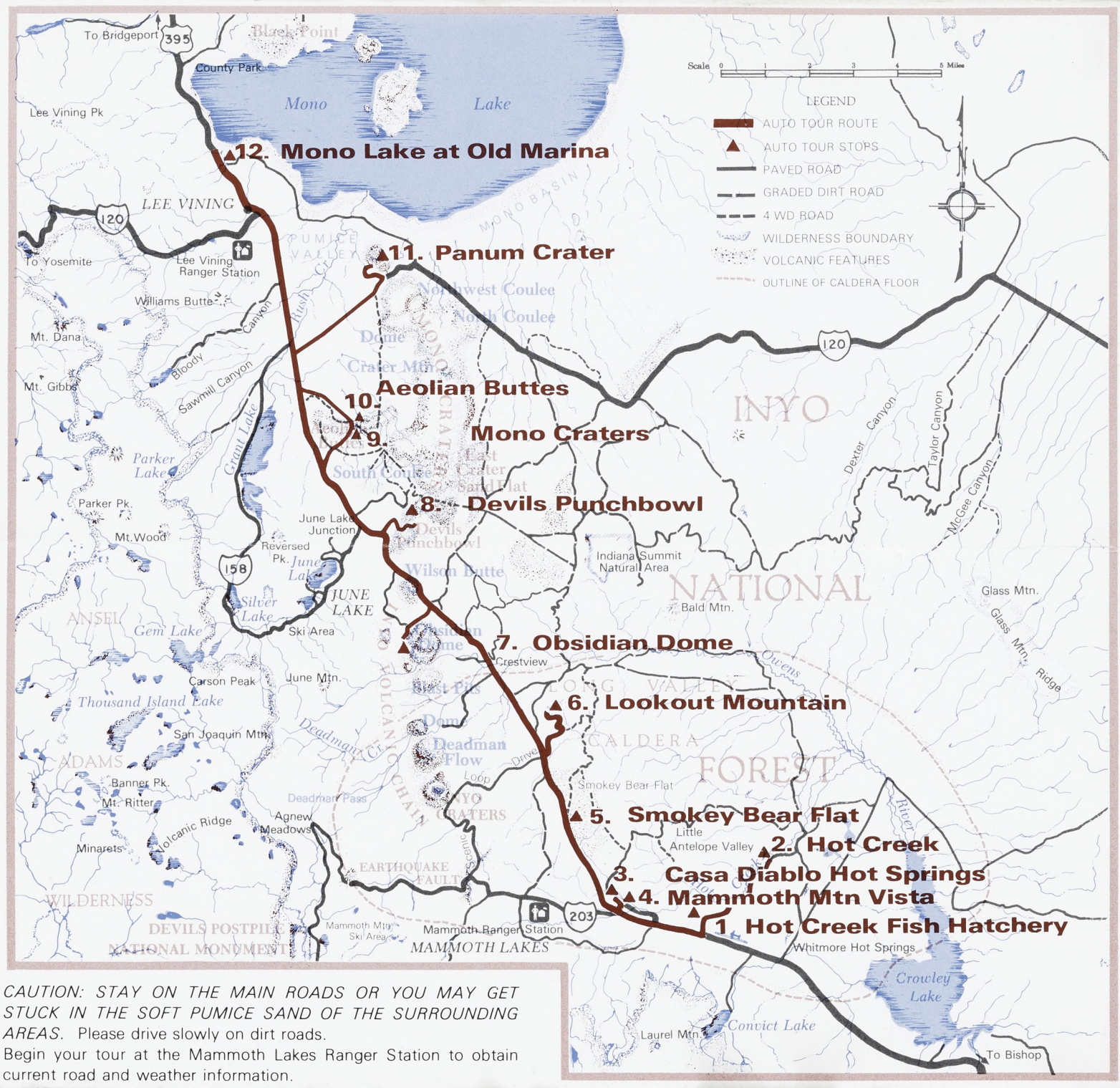
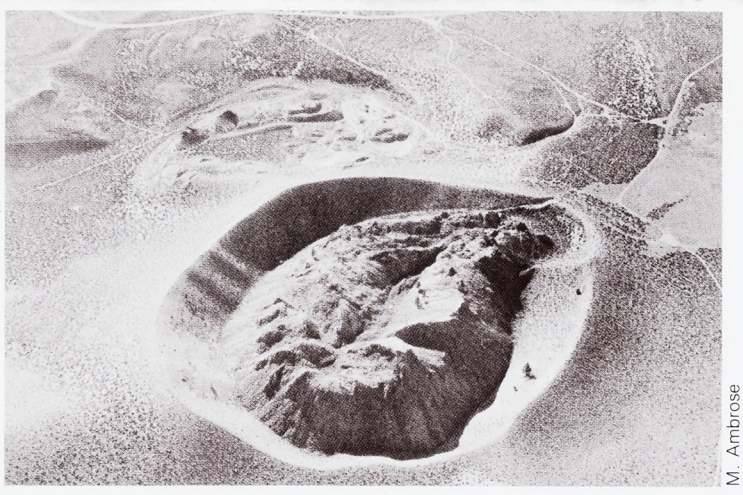


CAUTION: STAY ON THE MAIN ROADS OR YOU MAY GET STUCK IN THE SOFT PUMICE SAND OF THE SURROUNDING AREAS. Please drive slowly on dirt roads.
Begin your tour at the Mammoth Lakes Ranger Station to obtain current road and weather information.



M. Ambrose

11. PANUM CRATER *(North Hwy. 395 3.5 miles to Hwy. 120, then east 3 miles.)*

Panum Crater is a rhyolitic volcano and you are outside its rim. Listen carefully as you take the short walk to the exhibit shelter. Do you recognize the sound of grinding glass fragments underfoot? The chemistry of rhyolite is about 75% silica, the raw material of glass. Look at the rocks at your feet. What does their size tell you about the source of the eruption? Dig down a little. Does the size change?

Panum is one of the youngest volcanoes in the Eastern Sierra, erupting about 600 years ago. Its eruption followed the pattern of the Mono Craters, Devils Punchbowl and Mount St. Helens. For more information on the history of Panum, check the visitor box and exhibit shelter. Trails on the rim (1 hour) and interior (1 hour) of Panum let you explore the plug dome volcano.

12. MONO LAKE AT OLD MARINA *(Return to Hwy. 395 the same way you came, then north to 1.5 miles past Lee Vining. [Mono Lake Access])*

Mono Lake, the second-oldest lake in North America, is surrounded by volcanoes that erupted as much as 13 million years ago. The Bodie Hills, Anchorite Hills and Cowtrack Mountains, forming the far horizons northeast to east, are far older than the 700,000+ year old lake.

A short trail about ¼ mile southeast takes you to the shore where you will find pumice boulders crusted with tufa (too'-fuh). Thousands of feet of volcanic ash, deposited in the lake over the centuries, help make Mono Lake water extremely alkaline. Be sure to feel the water; does it feel slippery or soapy to you?

Additional information about Mono Lake ecology and tufa will be found in the exhibit shelter in this parking area and in the community of Lee Vining.

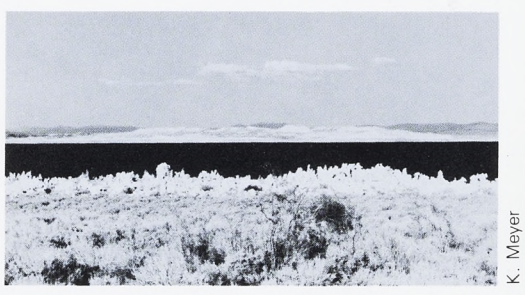
Hikers may wish to explore Black Point, east of the County Park (see map). A hiking map and information will be found at the Black Point parking area.

On the near horizon, the oldest visible volcano is **Black Point** This basaltic (ba-sal'-tic) volcano (rock similar to the Hawaiian volcanoes) erupted under water 13,000 years ago, when Mono Lake was much deeper. Unlike most basalt, Black Point's flow was quenched by the relatively cool water. This caused the lava to fracture into ash and small rock fragments called lapilli (la-pill'-ee) or pea-sized fragments.

Lapilli, also called cinders, is mined from Black Point and used on icy highways in Mono County to improve tire traction and hasten snow melt.

The dark cone-like island in Mono Lake is **Negit** (Ne-' git) **Island,** another basaltic volcano. Negit first erupted about 2,000 years ago, a few seconds ago in geologic time. Repeated extrusions (flows) created the craters and cone that you see. The most recent activity on Negit was about 220 years ago. While our founding fathers were signing the Constitution, volcanoes may have been erupting at Mono Lake.

Negit Island is important as a nesting site for thousands of California gulls. Israel Russell, an early geologist, gave the island its name which means "blue winged goose" in the local Paiute language.



K. Meyer

Paoha(Pay-oh'-hah), the light-colored island, is fine grained lake-bottom sediments pushed up from under the lake by a magma chamber. Paoha rose, rather than erupted, about the same time as the most recent activity on Negit. Paoha's ridges and cliffs were formed as the sediments slipped lakeward during the islands uplift. Both the north end of Paoha and Hot Springs Point, not visible from here, show the more common evidence of volcanic origin with cinder cones, lava flows and fumaroles.

Russell also named Paoha following the Native American tradition. He described the name to mean "diminutive spirits with long wavy hair emerging from hot springs."

Conclusion

As you review today's journey into the geologic history of the Mammoth and Mono Lake areas, you can look across Mono Lake to see some of the oldest landforms in the area (the horizon) and some of the youngest (the islands). The rest of the tour falls in the middle, from the 700,000-year-old Long Valley Caldera and Aeolian Buttes, to the resurgent dome of Lookout Mountain and Obsidian Dome and the Mono Craters. The volcanic story is not over, as seen from the boiling pools and warm springs of Hot Creek, the fish hatchery and the geothermal power plant.

The sites you have visited are classic examples of geologic events easily seen from local highways, yet there are still other interesting volcanic features throughout the Eastern Sierra. For example, with the help of an Inyo National Forest map, you can find the Deadman Creek area where many 2-wheel-drive roads provide access to half-million-year-old lava flows. East of the Mono Craters, 4WD roads will give you a more intimate view of domes, craters and pumice flats.

For more detailed information and additional sites to visit, the following books may be purchased at book stores, visitor centers and ranger stations.

Hill, Mary. Geology of the Sierra Nevada
Hill, Mary. California Landscape and Evolution
Smith, Genny (Editor). Earthquakes and Young Volcanoes

Printed by Eastern Sierra Interpretive Association, a nonprofit organization pledged to the scientific, educational, historic and interpretive activities of the Inyo National Forest.

K. Meyer

Devils Postpile National Monument

Your eye is now becoming accustomed to seeing the features of a volcanic landscape and you have learned some of the vocabulary. As you travel, look for Bishop tuff in the road cuts from June Lake to Bishop and in the "tablelands" of the Owens River Gorge. Have you seen the lava flows and cinder cones along Hwy. 395 from Bishop to Ridgecrest? Will you recognize other craters, cones and coulees as you travel the Eastern Sierra, eastern California and the Great Basin?

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